Chapter 8: Inheritance

CSE 2010 - Week 12

Background

In object-oriented programming, classes are not used in isolation, but instead used in relation to each other.

Consider the following classes:

- Animal
- Cat

The concept of an animal is a general one, while a cat is a specific type of animal. All cats are animals, but not all animals are cats.

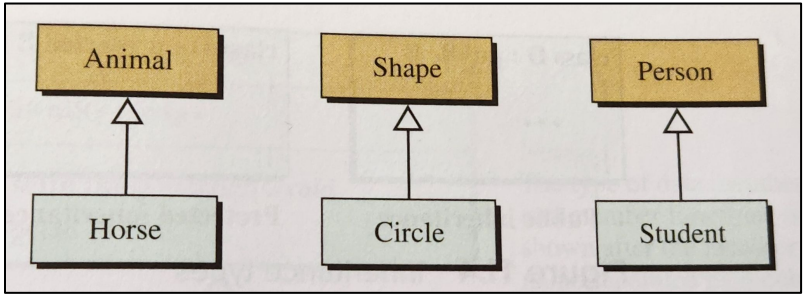
This is the concept behind ***inheritance.***

Inheritance

- Inheritance in object-oriented programming derives a more specific concept from a more general one.
- With inheritance, we have a **base** class and **derived** classes.
- **Base Class:**
  - A class that describes a general concept.
    - Person
    - Animal
    - Shape
    - Employee
- **Derived Class:**
  - A class that inherits from a base class and is a more specialized case.
    - Student
    - Cat
    - Circle
    - Manager

Unified Modeling Language (UML)

- To show the relationship between inherited classes in C++, we can use the Unified Modeling Language (UML).
- UML is a language that graphically shows the relationship between classes and objects.
- Classes are shown in rectangular boxes, while the inheritance relationship is shown by a solid line ending in a hollow triangle that goes from the specific class to the general class.



UML Diagrams denoting inheritance
Bottom: Derived Classes
Top: Base Classes

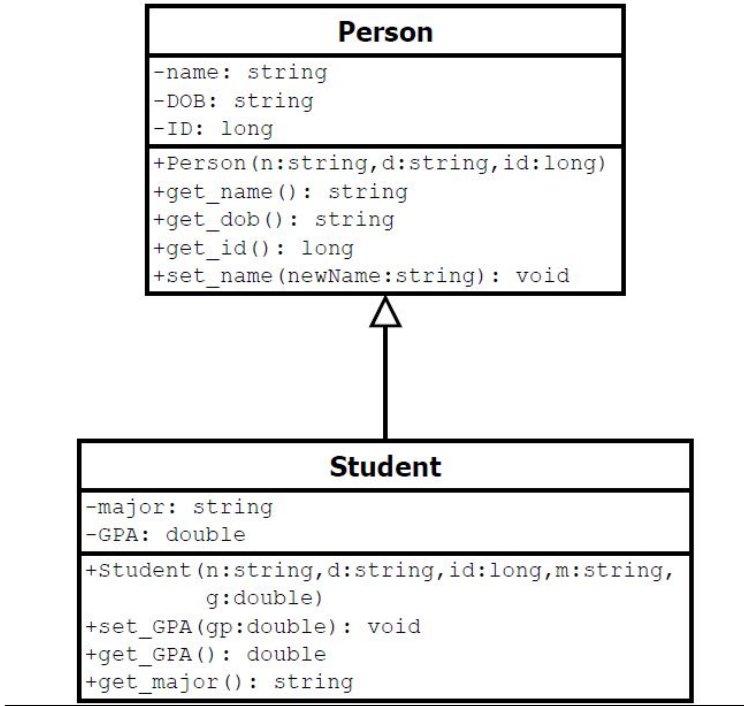
Relationship between the base and derived class

- A specific concept must have the characteristics of the general concept, but it can have more.
- In C++, we say that a derived class *extends* its base class, meaning the derived class must have all of the data members and member functions of the base class, but it can add to the list.
- There are 3 ways a derived class can inherit a base class:
  - Private inheritance
  - Protected inheritance
  - **Public inheritance**

- The default type of inheritance is private, but private and protected aren't really used.
- So in this class we will focus on public.
- If you want to learn more about private and protected inheritance, read me.

Consider the following classes...

- Person
  - A person has a name, date of birth (DOB), and ID #.
- Student
  - A student inherits the data members and member functions from Person.
  - Additionally, a student has a major and GPA.
- See a more extended UML Diagram to show the relationship between these classes →



- The type of data members and member functions is shown after the member names separated by a colon.
- The minus signs define the visibility of data members as private; the plus signs define them as public.

Class Definitions

```
Syntax for a derived class definition:

class DerivedClassName:public BaseClassName
{
};
```

Base Class: Person

```
/*
 * Filename: Person.h
 * Definition of the Person class
 */
#include <string>
using namespace std;
#ifndef PERSON_H
#define PERSON_H
class Person{
        private:
                string name;//a person's full name
                string DOB;//a person's date of birth
                long ID;//a peron's ID #
        public:
                Person(string n, string d, long id);//constructor
                ~Person();//destructor
                string get_name() const;//return name
                string get_dob() const;//return DOB
                long get_id() const;//return ID
                void set_name(string newName);//update name

};
#endif
```

Derived Class: Student

```
/*
 * Filename: Student.h
 * Definition of the Student class, which inherits the Person class
 */
#include "Person.h"
#ifndef STUDENT_H
#define STUDENT_H
class Student:public Person{
        private:
                string major;//student's major
                double GPA;//student's GPA
        public:
                //note how many parameters the derived class constructor has
                Student(string n, string d, long id, string m, double g);
                ~Student();
                void set_GPA(double gp);
                double get_GPA()const;
                string get_major()const;
};
#endif
```

Student inherits all member functions and data members of the Person class.

Defining the Derived Class Constructors

- The constructor(s) of a derived class has two tasks:
  - Initialize the base object
  - Initialize its own data members

Syntax:

```
DerivedClassName::DerivedClassName(parameters)
:BaseClassName(parameters for base class),initialization list for remaining data members
{


}
```

Class Member Function Definitions

Base Class: Person

```cpp
/*
 * Filename: Person.cpp
 * Definition of the Person class member functions
 */
#include "Person.h"

//constructor
Person::Person(string n, string d, long id):name(n),DOB(d),ID(id){
}
//destructor
Person::~Person(){
        cout << "Destorying Person object with name: " << name << "\n";
}
//getters that return private data members
string Person::get_name()const{
        return name;
}
string Person::get_dob()const{
        return DOB;
}
long Person::get_id()const{
        return ID;
}
//update person's name
void Person::set_name(string newName){
        name = newName;
}
```

Derived Class: Student

```cpp
/*
 * Filename: Student.cpp
 * Definition of Student class member functions
 */
#include "Student.h"
//constructor that invokes Base class constructor
Student::Student(string n, string d, long id, string m, double g)
        :Person(n,d,id), major(m),GPA(g){
}
//destructor
Student::~Student(){
        cout << "Destorying Student with name: " << get_name() << "\n";
}
//update GPA
void Student::set_GPA(double gp){
        GPA = gp;
}
//getters to return private data members
double Student::get_GPA()const{
        return GPA;
}
string Student::get_major()const{
        return major;
}
```

Main.cpp

```cpp
/*
 * Filename:main.cpp
 * Program that uses the Person and Student classes
 */
#include <iostream>
#include "Student.h"
using namespace std;

int main()
{
        //Declare a Person object
        Person person1("Fred Rogers","03-20-1928",100003);
        cout << "Person Name: " << person1.get_name() << "\n";
        cout << "\tDOB:" << person1.get_dob() << "\n";
        cout << "\tID:" << person1.get_id() << "\n";

        //Declare a Student object
        Student student1("Bob Ross","10-29-1942",100005,"Art",4.0);
        cout << "Student Name: " << student1.get_name() << "\n";
        cout << "\tDOB: " << student1.get_dob() << "\n";
        cout << "\tID: " << student1.get_id() << "\n";
        cout << "\tMajor: " << student1.get_major() << "\n";
        cout << "\tGPA: " << student1.get_GPA() << "\n";

        return 0;
}
```

makefile

```
main: main.o Student.o Person.o
        g++ -o main main.o Student.o Person.o
main.o: main.cpp Student.h
        g++ -c main.cpp
Student.o: Student.cpp Student.h
        g++ -c Student.cpp
Person.o: Person.cpp Person.h
        g++ -c Person.cpp
```

Let's run this to see what we get!

Overloaded vs Overridden Member Functions

- It is possible to have functions with the same name in the base class and its derived class(es).
- **Overloaded Member Functions:**
  - Functions with the same name, but different parameters.
  - They can be used in the same or different classes without being confused with each other.
  - Consider the following:

Person Class	Student Class
`void set(long newID);`	`void set(string newMajor);`

- A student object could use both functions, depending on what the parameter datatype is, the compiler would use the appropriate one.
- A person object could only use it's own set() function.

- **Overridden Member Functions:**
  - Functions with the same name and same parameters.
  - Consider the following:

Person Class	Student Class
`void print();`	`void print();`

- The compiler will default to use the function that belongs to the class of the object that has invoked it.
- It is possible to delegate a specific function. For example, if a Student member function wanted to call the print function for person, we could write
  - Person::print()

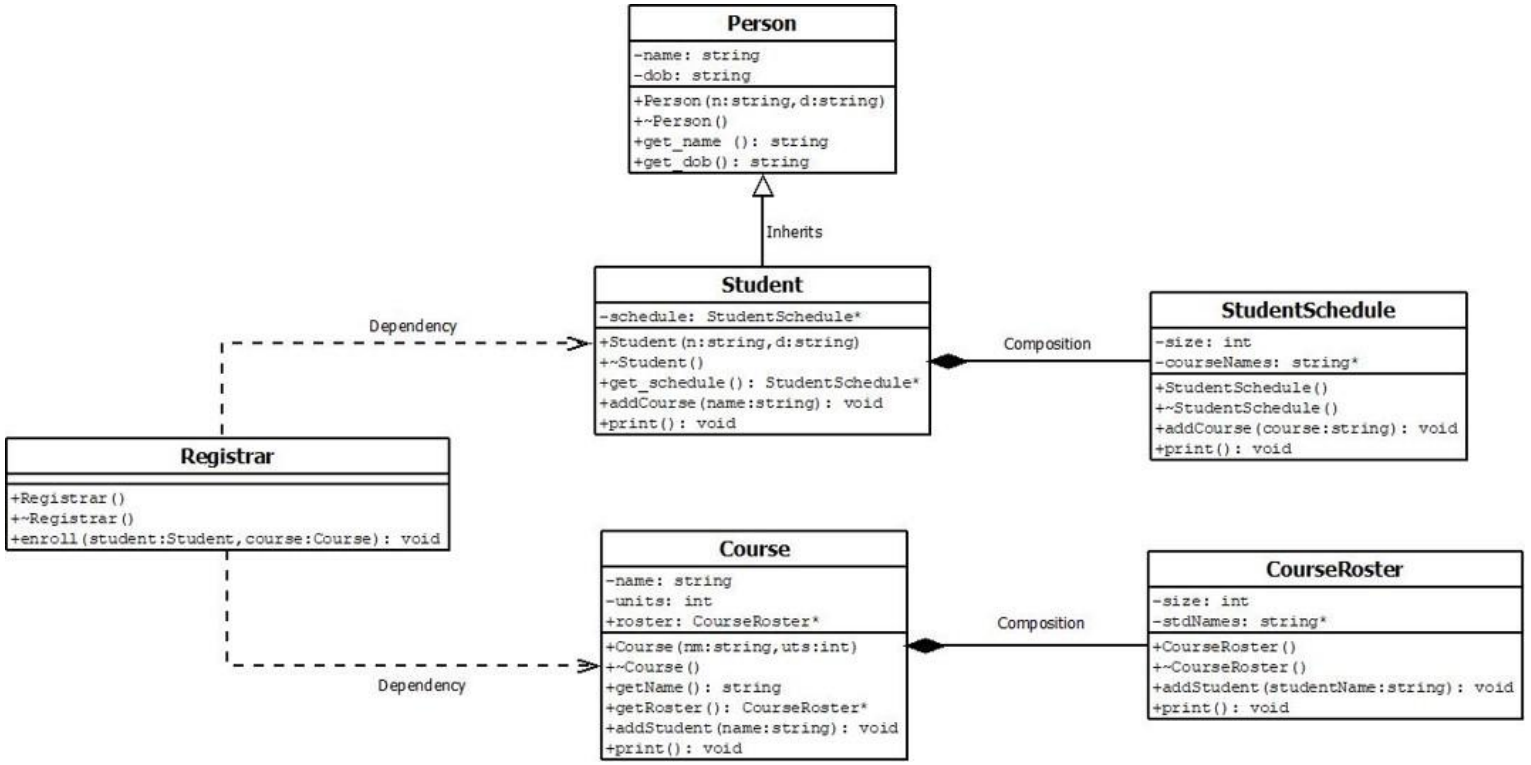
Dependencies and Compositions

- Not all relationships between classes can be described as inheritance.
- **Dependency:**
  - Class A depends on Class B if Class A somehow uses Class B.
  - Class A depends on Class B if Class A cannot perform its complete task without class B.
    - Example:
      - Last chapter we had an Employee class and a Department class.
      - The Department class had two Employees: A receptionist and a secretary
  - For UML, dependency between classes is denoted with a dotted line ending with an arrow.
- **Composition:**
  - Describes the relationship between two classes where Class A has a Class B, and the lifetime of the Class B object depends on Class A.
  - Class B cannot exist without Class A.
  - For UML, composition between classes is denoted with a solid line ending with a solid diamond.

Registration System Example

- Lets design a simple registration system for a small department at a university.
- There will be some inheritance, dependency, and composition.
- We will use 6 classes:
  - **Person:** Contains a name and DOB
  - **StudentSchedule**: Contains a size (int) and course names (array of strings)
  - **Student**: Inherits the Person class. Additionally contains a schedule (StudentSchedule)
  - **CourseRoster**: Contains a size (int) and a roster of students (array of strings)
  - **Course**: Contains a name(string), # of units (int), and a roster (CourseRoster)
  - **Registrar**: Uses the Student and Course objects

Registration System UML Diagram



Person Class

```
/*
* Filename: Person.h
* Person class definition
*/

#ifndef PERSON_H
#define PERSON_H
#include <string>
#include <iostream>

using namespace std;

class Person
{
        private:
                string name; //name of person
                string dob; //date of birth
        public:
                Person(string n, string d); //constructor
                ~Person(); //destructor
                string get_name() const;//return name
                string get_dob() const;//return dob
};
#endif
```

```
/*
 * Filename: Person.cpp
 * Person class member functions
 */
#include "Person.h"

//constructor
Person::Person(string n, string d):name(n),dob(d){
}
//destructor
Person::~Person(){
}
//get functions to return private data members
string Person::get_name()const {
        return name;
}
string Person::get_dob ()const{
        return dob;
}
```

Student Schedule Class

```h
/*
* Filename:StudentSchedule.h
* StudentSchedule Class Definition to represent a student's schedule
*/

#ifndef STUDENTSCHEDULE_H
#define STUDENTSCHEDULE_H
#include <string>
#include <iostream>
using namespace std;

class StudentSchedule{
        private:
                int size;//# of courses
                string* courseNames;//pointer for string array
        public:
                StudentSchedule();//default constructor
                ~StudentSchedule();//destructor
                void addCourse(string course);//add course to schedue
                void print() const;//print whole schedule
};
#endif
```

```cpp
/*
* Filename: StudentSchedule.cpp
* StudentSchedule class member function definitions
*/

#include "StudentSchedule.h"

//constructor to initialize number of classes to zero
StudentSchedule::StudentSchedule()
:size(0)
{
        //declares a new array of strings in heap memory
        courseNames = new string[5]; //students can have a max of 5 classes
}
//destructor
StudentSchedule::~StudentSchedule(){
        //will delete the array we created in heap memory
        delete[] courseNames;
}

void StudentSchedule::addCourse(string name){
        //the parameter 'name' has a course name
        //size will start at 0, and will increase as more classes are added
        courseNames[size] = name;
        size++;
}
void StudentSchedule::print() const{
        //print the full student schedule
        cout << "\tList of Courses:\n";
        for(int i = 0; i < size; i++){
                cout <<"\t\t"<<i+1<<":"<< courseNames[i] << "\n";
        }
        cout << "\n";
}
```

Student Class

```
/*
* Filename: Student.h
* Student Class Definition
*/

#ifndef STUDENT_H
#define STUDENT_H
#include <string>
#include <iostream>
#include "StudentSchedule.h" //Uses a Student Schedule
#include "Person.h"//inherits Person

using namespace std;

class Student:public Person //inherits Person class
{
        private:
                StudentSchedule* schedule;//Each student has their own schedule
        public:
                Student(string n, string d);//constructor
                ~Student();//destructor
                StudentSchedule* get_schedule() const;//return schedule
                void addCourse(string name);//add a course
                void print() const;//print student info
};
#endif
```

```
/*
 * Filename: Student.cp
 * Student member function definitions
 */
#include "Student.h"
//constructor that invokes base class constructor
Student::Student(string n, string d):Person(n,d)
{
        //creates a new Student Schedule object pointer
        schedule = new StudentSchedule;
}
Student::~Student()
{
        //destructor does not need to delete schedule
        //since schedule is a pointer to a pointer
}
StudentSchedule* Student::get_schedule() const{
        return schedule;
}
void Student::addCourse(string name){
        //invoke addCourse function from StudentSchedule
        schedule->addCourse(name);
}
void Student::print() const{
        //print student info
        cout << "Student name: " << get_name() << "\n";//base class
        cout << "\tStudent DOB(MM-DD-YYYY): " <<get_dob() << "\n";//base class
        schedule->print();//calls print of StudentSchedulei

}
```

Note: When dealing with object pointers, we've been using the notation: (*objectName).functionName(),
But we can also use: objectName->functionName().

Course Roster Class

```h
/*
 * Filename:CourseRoster.h
 * CourseRoster Class Definition
 */
#include <string>
#include <iostream>
using namespace std;

#ifndef COURSEROSTER_H
#define COURSEROSTER_H
class CourseRoster{
        private:
                int size;//number of students in a course
                string* stdNames;//a string pointer
        public:
                CourseRoster();//constructor
                ~CourseRoster();//destructor
                void addStudent(string studentName);//add student
                void print() const;//print enrolled students
};
#endif
```

```cpp
/*
 * Filename: CourseRoster.cpp
 * CourseRoster class member function definitions
 */
#include "CourseRoster.h"
//constructor that starts off with zero students
CourseRoster::CourseRoster():size(0){
        //use pointer to create new string array in heap memory
        stdNames = new string[20]; //course has max 20 students
}
CourseRoster::~CourseRoster(){
        //delete array in heap memory
        delete[] stdNames;
}
void CourseRoster::addStudent(string studentName){
        //add a student to the roster
        stdNames[size] = studentName;
        size++;//increase roster size by 1
}
void CourseRoster::print() const{
        //print list of students
        cout << "\tList of Students:\n";
        for(int i = 0; i < size; i++)
        {
                cout <<"\t\t"<< i+1 << ": " << stdNames[i] << "\n";
        }
        cout << "\n";
}
```

Course Class

```h
/*
 * Filename: Course.h
 * Course class definition
 */
#include <string>
#include <iostream>
#include "CourseRoster.h"
using namespace std;

#ifndef COURSE_H
#define COURSE_H
class Course{
        private:
                string name;//name of course
                int units;//number of units for course
                CourseRoster* roster;//roster of students for a course
        public:
                Course(string nm, int uts);//constructor
                ~Course();//destructor
                string getName() const;//return course name
                CourseRoster* getRoster() const;//return roster
                void addStudent(string name);//add student to course
                void print() const;//print course info
};
#endif
```

```cpp
/*
 * Filename: Course.cpp
 * Course class member function definitions
 */
#include "Course.h"
//constructor to initialize data members and roster
Course::Course(string nm, int uts):name(nm),units(uts){
        //point roster to pointer in heap memory
        roster = new CourseRoster;
}
Course::~Course(){
        //don't need to delete since roster is a pointer
        //to a pointer
}
string Course::getName() const{
        return name;//return course name
}

CourseRoster* Course::getRoster() const{
        return roster;//return class roster
}

void Course:: addStudent(string name){
        //invoke addStudent() from CourseRoster class
        roster->addStudent(name);
}
void Course:: print() const{
        //print course info
        cout << "Course Name: " << name << "\n";
        cout << "\tNumber of Units: " << units << "\n";
        //invoke print() from CourseRoster class
        roster->print();
}
```

Registrar Class

```h
/*
 * Filename: Registrar.h
 * Registrar class definition
 */
#ifndef REGISTRAR_H
#define REGISTRAR_H

#include "Course.h"//uses Course class
#include "Student.h"//uses Student class

class Registrar
{
        public:
                Registrar();//constructor
                ~Registrar();//destructor
                void enroll(Student student, Course course);
        //no private section
};
#endif
```

```cpp
/*
 * Filename: Registrar.cpp
 * Registrar class member function definitions
 */

#include "Registrar.h"

//empty constructor and destructor
Registrar::Registrar(){
        //nothing
}
Registrar::~Registrar(){
        //nada
}
//function to enroll a student in a course
void Registrar::enroll(Student student, Course course)
{

        //(course.getRoster()) is going to return the roster for a course
        //then we use that roster to invoke addStudent() from the CourseRoster class
        (course.getRoster())->addStudent(student.get_name());

        //(student.get_schedule()) is going to return the student's schedule
        //then we use that schedule object to invoke addCourse() from the StudentSchedule class
        (student.get_schedule())->addCourse(course.getName());
}
```

Now that we've defined all our classes, lets see a program that uses them.